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Research Article

AN IMPROVEMENT OF ELECTROMAGNETIC FIELD METHOD TO REDUCE FLUORIDE CONTENT IN WATER

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ABSTRACT

Fluoride in water in excess of 1.5mg/L is indicated by medical reports as a hazard to human health, it causes enamel damage, osteoporosis. The electrocoagulation method (EC) is widely used because of its effectiveness, safety, and economy. However, the current EC method has not been designed as a reactor. In this research, the EC reactor was designed using an aluminium pole and a container was used to remove F- from the water. The design of the new EC has eliminated the need for a water mixer, the ability to remove F- from the aggregate water of the new EC unit is evaluated at different current densities (CD) (1–3 mA/cm2)), electrode distances (ELD) (5–15 mm), pH of the solution (pHoS) (4–10), and initial F- concentrations (IFC) (5–20 mg/L). Experimentally, the results of this study demonstrate that the new reactor can remove up to 98.3% of 20 mg/l F- at CD, ELD, pHoS and IFC of 2 mA/cm2. 5 mm and 4 and 10 mg/L, respectively.

Index Terms— fluoride removal, aluminum electrodes, electrocoagulation

INTRODUCTION

The literature and technical reviews rank fluorine as the 17th maximum abundant element in nature as it represents up to zero.6% of the crust of the Earth planet [1]. as an instance, the to be had literature has indicated that a few herbal formations, inclusive of fluorspar, include multiplied fluoride concentrations (F-). therefore, weathering of such formation's outcomes inside the enrichment of freshwater with high F concentrations, so this element is expected to be excessive in freshwater bodies [2]. similarly, F- attention in groundwater (aquifers), the primary supply of drinking water in arid and semi-arid areas, is normally increased because of water filtration via natural formations before accomplishing the aquifers [3,4]. The literature demonstrates that aquifers' common F- awareness is two–10 mg/L [5]. except the herbal existence of F- in freshwater, the industrial revolution brought about a dramatic boom in F- concentrations in the aquatic environment [6,7]. as an example, the effluents of semiconductors and aluminum industries are very rich in F, that's dumped into surface waters [8,9].

The recent scarcity of fresh water due to climate change and population growth also contributes to the increased problem of water pollution [10,11]. F in fresh water at high concentrations is the cause of many diseases; F 1.5 mg/L has been reported to cause stiffness, bone weakness, and enamel fluorosis [12]. Therefore, the World Health Organization (WHO) has limited the concentration of F in drinking water to 1.20 mg/L [13]. Various treatment modalities are performed to reduce the intake of F- and drinking water to maximum capacity, 1.2 mg / L, including but not limited to membranes, rain, ion exchange and diffusion [14]. However, many of these methods suffer from setbacks that hinder their widespread use, mainly in economic development [15]. For example, technology reports have shown the value of advanced skin technology and the need for therapeutic devices to avoid contamination [16]. The media path has some limitations, including the depletion of adsorbents and the high production value of some types of adsorbents [17]. Weaknesses of other aforementioned methods have been discussed in detail in some research projects [18,19]. The need for effective water treatment is growing rapidly due to severe water scarcity due to climate change.

In this study, an electrocoagulation (EC) method to expand water was adopted because of the unique advantages of this method. EC is known as a cost-effective, safe, simple and easy to operate system [20,21]. Most importantly, EC is an environmentally friendly system as it depends on the generation of coagulant without the need for chemical additives; that is, it does not produce secondary contamination or toxic sludge [5]. These unique benefits have encouraged researchers and institutions to use the EC system in many areas for the treatment of wastewater and wastewater. For example, Ouaissa et al. [22] Using aluminum cell molding aluminum electrodes to remove chromium Cr (VI) from synthetic water. The best extraction obtained is 97% at a current density of 4.03 mA · cm-2 with an initial pH of 3–6. Naja et al. [23] Remove the Imperon violet KB dye with a cotton swab (EC) aluminum unit. The results showed that the optimum color removal was about 98%, obtained after 10 min at a current density of 4 mA cm-2, pH of approximately 5, and a water temperature of 25 ◦ vs. Another study on the elimination of E. coli from water using the EC method was Castro-Rios et al. [24]. This study used 500 mL suspended EC cell and aluminum electrodes to formulate a synthetic liquid sample containing 105–106 cfu / mL of E. coli. The results of the study confirmed that EC cell function at a current density of 2.27 mA / cm2, an initial pH of 4 and 2.5 mg / L Na2SO4 was sufficient to reduce E. coli concentrations of 1.0- and 1.9- log after 40 min. 90 min, one at a time.

There is a large body of paper demonstrating the effectiveness of EC in removing many contaminants from water and wastewater in a short period of time, such as [25 - 29]. However, CE has no setbacks; some researchers have shown a few drawbacks: (1) High pH effects on chemical solutions and EC performance [30], and (2) lack of adequate regulatory control, whereas most EC reactors now uses a simple quadrilateral, cylindrical or square reactors with individual electrodes installed [13]. Furthermore, models available to maximize the efficiency of EC reactors are still limited [31]. Therefore, as an attempt to improve one of these weaknesses, this study demonstrates a new regulation of EC and its use to remove F- and synthetic water. The removal of the F- is intended to achieve two goals: first, to demonstrate the ability of the new reactor to function as an EC, and second, to provide a new efficient and effective method of water treatment. Details of the new EC reactor are described in the test procedure in the next section.

MATERIALS AND METHODS

Chemicals and Solution:

Chemicals needed to be tested in this study, including NaF, NaOH, NaCl, and HCl, from Merck, Darmstadt, Germany, were used. The synthetic solution was originally prepared by adding 442 mg of NaF into deionized water to obtain a product solution mixed with an F solution of 200 mg / L. The weight of NaF powder was carefully measured using a four-factor scale (GRAM-FS, Gram Group, Barcelona, Spain). The solution was stirred using a magnetic field (RS PRO Stirrer - SH4, Merck, Darmstadt, Germany) until the powder was completely dissolved; It is then refrigerated and used to prepare samples containing low F (IFC) concentrations (from 5 to 20 mg / L). The initial pH of the solution (pHoS) was converted to the desired value (4 to 10) using hydrochloric acid or sodium hydroxide, and the pHoS value was measured using a meter (Model: HI 98130, Merck, Darmstadt, Germany). The initial electrical conductivity of the synthetic sample was maintained at 320 µS / cm using sodium chloride. The pHoS was measured in electrical current using a hand meter (type: HI 98130).

New EC Reactor:

The new bench EC reactor has been designed and manufactured to reduce water mixers and energy consumption. The new EC placed four drilled aluminum electrodes in a narrow section of the reactor. Each electrode was 6.5 cm long and 4.2 cm wide and had six vertical sections (4.5 cm long and 0.2 cm wide). The effective water depth inside the reactor is 5.5 cm, so the submerged area of each electrode is 33.2 cm2. The main body of the reactor, as shown in Figure 1, is made of plexiglass. The shape of the reactor is 12 cm wide due to the size of the reactor, the center shrinks to only 4 cm and then expands again to 12 cm at the end of the reactor.

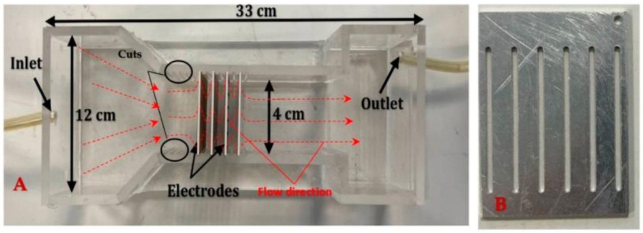

Figure 1: (**A**) The new EC reactor, (**B**) electrode

Additionally, 1mm is cut along the sides of the reactor in the narrowest part of the reactor (every 5mm of the length of the narrow part), which is then held to hold the electrodes in the desired area (electrode settings distances (ELD). .)). The purpose of the narrow cross section between the reactor is to increase the water velocity here. The presence of perforated electrodes in this critical area (very high speed) helps to mix water efficiently without the need for outdoor water heaters, such as flowing water. bad roads, as shown in picture 1. It should be noted that the performance is effective.

Demonstrated electrodes perforated in a mixture of water and paper [32,33]. The electrodes are connected to a DC source (HQ Power-30 V, Velleman Group, Gavere, Belgium) and peristaltic water pump (Watson-504U, Gemini Equipment, Apeldoorn, Netherlands) to distribute water through the new EC.

Experiments:

Initially, the rapid change in the wide and narrow area of the new EC was measured using the following equations:

$$V = \frac{Q}{A} \qquad (1)$$

where V, Q and A are the velocity (m / s), flow rate (m3 / s) and reactor cross section (and required area) respectively. F-removal test was then initiated by transferring contaminated water samples from the new EC to be cured for 30 min at different pHoS (4–10), current density (CD) (1- 3). mA/cm2), ELD (5-15 mm), IFC (5-20 mg / L) and IFC (from 5 to 20 mg / l). Depression was measured using the Hach-Lang spectrophotometer (DR-2800) and the Hach-Lange F-cuvettes (LCK323) (after dissection if the F- cuvette input was higher than that of the unit). The removal efficiency F- is measured by (2):

$$R(\%) = \frac{(C_1 - C_2) * 100\%}{C_1} \qquad (2)$$

where C1 and C2 are the beginning and trough total F- (mg/L), respectively. After each experiment, electrodes were removed from the EC to HCl (35%) and rinsed with water before being used for subsequent use. All experiments were performed for 30 min at the time of treatment used in previous studies, according to studies by Essadki et al. [34] and Hashim et al. [2]. Then the optimal processing time is determined in the experiment. Finally, for example, 5 liters of water was extracted from Tigris River, Tikrit City, Iraq on February 27, 2022. The sample was taken using a plastic bag and immediately transferred to laboratory and solidified fluoride at 10 mg/L. It is then processed using a new EC cell under optimal conditions obtained from a synthetic water sample. All experiments were repeated three times to ensure reliable results.

Operating Cost:

The service cost of the new EC was calculated using the equation (3) [35], which is suitable for laboratory conditions where it does not include wages, capital and sludge treatment. Prices for coal and steel units are estimated based on local Iraqi markets.

$$Operational\ cost\ (\frac{\$}{m^3}) = \beta \times Electrodes\ consumption + \gamma \times Energy\ consumption \qquad (3)$$

where α and β are metal and power unit prices, respectively. The power usage is calculated as follows:

$$Power\ usage\left(\frac{kWh}{m^3}\right) = \frac{Voltage \times Current \times Time}{Volume\ of\ water} \qquad (4)$$

Consumption of electrodes was measured as the difference in weight of the electrodes before and after treatment. The weight difference was measured using four-decimal (FA2004B, Gram Group, Barcelona, Spain).

RESULTS AND DISCUSSION

Removal F- from synthetic water extraction tests have been performed in several procedures, were:

Effects of CD on F- Removal:

Synthetic water samples were passed at 10 mg/L from the new EC for 30 min and delivered in three different CD sizes (1, 2, 3 mA · cm^{-2}). ELD and pHoS were measured at 10 and 4 mm respectively. The results of these experiments are shown in Figure 2A, which shows a clear change in the extraction of F- by water and changes in the applied CD (between 1 and 3 mA / cm^2). Overall, the F-powered CD discharge is enhanced, reaching full discharge 20 minutes later on a CD of 3 mA / cm^2. For CD values below 3 mA / cm^2, the F- depletion did not achieve complete elimination. A significant number of studies describe the effect of CD removing toxins from the EC system [36,37]. The increase in the removal of contaminants on the CD is due to the effect of the melting electric field of the ion metal from the anodes, which results in higher efficiency. The results of this study are well documented in the literature [38,39].

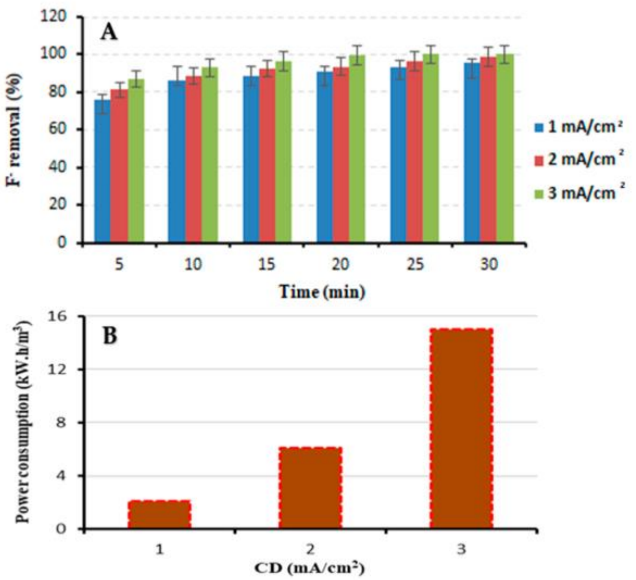

Figure 2: Effects of CD on (**A**) F- removal and (**B**) power consumption

In addition to the positive effects of DC increase and F output, there are negative effects of DC on EC function, whereas DC increase is found to increase energy consumption, as shown in Figure 2B. Therefore, a DC of 2 mA / cm2 is accepted here as the best value as it achieves good extraction performance (92.4%) and good power compared to a DC of 3 mA / cm^2.

Effects of pHoS on F- Removal:

Based on the results obtained in section 3.1, the pHoS test was performed on a CD of 2 mA / cm2 for 20 min, maintaining the ELD constant at 10 mm. Three pHoS levels were discussed in this study, namely, 4, 7, and 11. Figures 3 show the effect of different pHoS on the F. F. Optimal removal of the F- (93.4%) is found in pHoS acidic (4), but beyond this value, F-depletion decreases slightly to 89.2% at pHoS of 7 and 80.1% at pHoS of 11 here to avoid the need for acid addition, which has a negative impact on the environment. This change in F- elimination in pHoS is due to changes in the amphoteric properties of Al hydroxide. Importantly, low-alloy aluminum has a low adsorption capacity for F-, since it is less acidic and neutral, the most common aluminum type is Al (OH) 3, which has better adsorption capacity for F- [13]. The results of this part of the study correspond to that of the literature [2,13].

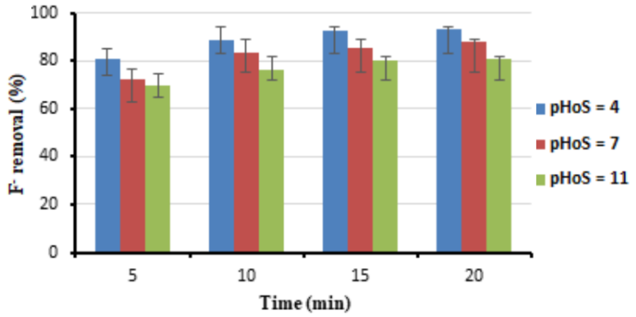

Figure 3: Effects of pHoS on F- removal by the new EC

Effects of ELD on F- Removal:

In this section, the effects of the ELD on the removal of F- by the new EC was investigated using the best values of the DC and pHoS obtained from the above results. The contaminated water samples were treated in the EC at three levels of ELD, namely 5, 10, and 15 mm, for 20 min. The results of this investigation are shown in Figure 4, which indicates the negative impact of the long ELD on F- removal. The best removal efficiency (98.3%) was achieved at the shortest ELD (5 mm); beyond this distance, the removal efficiency decreased to 81.3% at an ELD of 15 mm. The literature attributes this decrease to the drop in the electric current flow between the electrodes (decrease in electric field intensity), which decreases the melting of metal ions from the anodes and consequently decreases the removal efficiency [40,41]. The outcomes of this investigation encourage the authors to select the ELD of 5 mm to achieve the best removal efficiency of F-

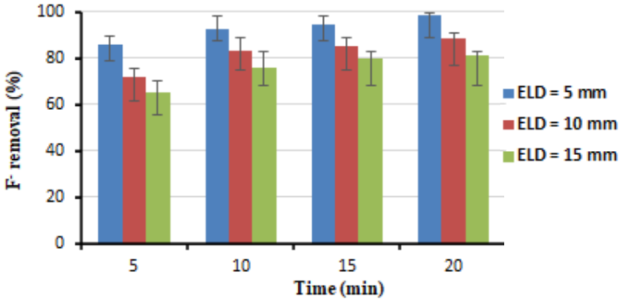

Figure 4: Effects of ELD on F Effects of ELD on F - removal by the new EC. - removal by the new EC

Effects of IFC on F- Removal:

The effect of pollutant concentration on the efficiency of the EC was studied for three concentrations of F-, namely 5, 10, and 20 mg/L. The results of the investigation can be observed in Figure 5, which confirms that the removal efficiency of the high F- concentration was less than the removal of low F-concentrations. The relevant studies in the literature [42,43] relate the drop in the removal efficiency with the increase in F- concentration to the fact that the high concentrations of F- require more aluminum ions, which increase the required time to accomplish the complete removal.

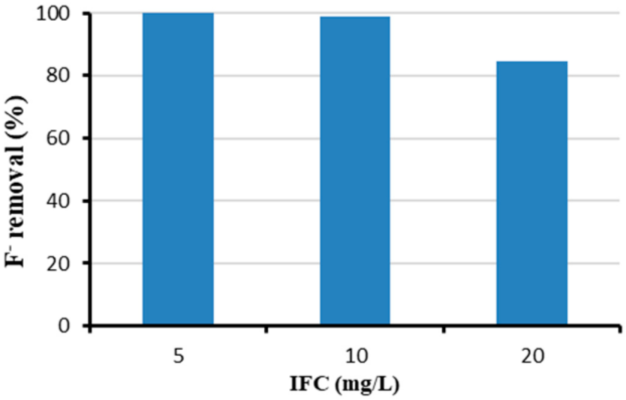

Figure 5: Effects of IFC on F- removal by the new EC

The reproducibility of CE obtained is similar to that of water-repellent materials [5, 44], which supports one of the most important advantages of new CE. The new EC uses a container configuration with electrodes, which allows the speed to circulate between the reactor cores and force water to flow through the airway. According to equation (1), the velocity in the narrow area of the reactor is 3 times the velocity in the wide area (input reactor), and the velocity in the vertical termination of the electrodes is 12 times the velocity in the region. . input reactor. Therefore, the treated water should be thoroughly mixed without the need for mixers. Finally, for comparison, natural liquid samples, derived from Tigre, contain 10 mg / L, treated under optimum operating conditions (CD of 2 mA / cm2, pHoS 7 and ELD of 5 mm). The treatment is continued until fluoride is completely removed from the natural water sample. The results from these experiments are shown in Figure 6, which shows that the progress of fluoride removal is slower than that of synthetic water.

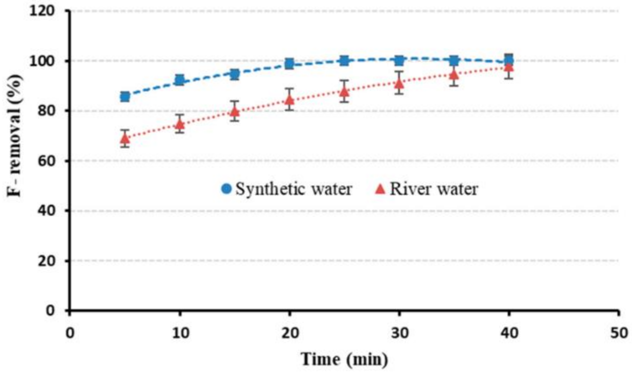

Figure 6: Comparison between fluoride removal from synthetic and river water samples

Power Consumption and Operating Cost:

The energy consumption of the EC reactor is calculated during the F- extraction by using the scale (4) under the optimum operating conditions to obtain the optimum discharge function (98.3%), i.e. ELD of 5 mm, IFC of 10 mg / L, CD. of 2 mA / cm2, pHoS of 4 and treatment time of 20 min. The rated power consumption is 4.06 kW · h / m3. Calculated energy consumption, as well as the amount of aluminum consumed, are also used to calculate labor costs as equals (3). The price of electricity and aluminum is projected according to the Iraqi market as of January 2022, which is 2.4 cents / kWh for electricity and 3.00 USD for 1.0 kg of aluminum. The total operating cost is 0.292 USD per m3 of purified water, which is lower than the paper reported, as 0.358 USD / m3 [45] and 0.354 USD / m3 [46], which is often referred to as the elimination of the need for agitators. Considering that this price is for laboratory laboratories, which is lower than the cost of the field as the latter covers other more expensive items, such as labor and sludge processing costs.

CONCLUSIONS

The presented study investigates the design and use of a new EC reactor to remove F- from water. The obtained results demonstrate the following:

1. The new EC reactor can remediate water from F-, with an efficiency of 98.3%.
2. The new design of the reactor and the electrodes reduce the need for external water mixers, which in turn

minimizes the power consumption.

3. The removal of F- by the EC increases with the applied CD but decreases with the increase of pHoS, ELD, and IFC.
4. The calculated operating cost of the new EC reactor was slightly cheaper in comparison with the traditional electrocoagulation reactor.

There is room for future applications of the new EC, such as using it to remove heavy metals, nitrate, and phosphate from water or wastewater.

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